University of California
Lawrence Livermore National Laboratory
Director's Office

November 1995
UCRL-MI-121431-DO

The Lawrence Livermore National Laboratory serves the nation through innovative science and technology

Mission

As a multiprogram, multidisciplinary, national-security laboratory, the Lawrence Livermore National Laboratory focuses its talents and resources on:
- Stockpile stewardship and global security—reducing the nuclear danger.
- Energy and environment—balancing economic development and environmental protection.
- Bioscience—revolutionizing the understanding of human health.

People and Facilities

One of the largest research institutions in the world, Livermore's staff of some 7000 employees includes more than 2500 scientists and engineers and 2500 craftspeople and technicians. Its research complex includes lasers, supercomputers, accelerators, and hundreds of laboratories and test facilities. Through its long association with the University of California, Livermore has been able to recruit a world-class workforce and to establish an atmosphere of intellectual freedom and innovation, both of which are essential to sustained scientific and technological excellence.

Programs and Directorates

Livermore's programs derive from our core capabilities, building on discoveries and applying computer codes and technical innovations developed in the course of our national-security work. An infrastructure of disciplinary departments supports our programs and provides the foundation for our scientific and technical capabilities.

Program Directorates	Supporting Directorates
• Defense and Nuclear Technologies	• Chemistry and Materials Science
• Nonproliferation, Arms Control, and International Security	• Physics and Space Technology
• Lasers	• Computations
• Energy	• Engineering
• Environmental Research	• Plant Operations
• Bioscience and Biotechnology Research	

Benefits to the Nation

Livermore's hallmark is the ability to translate basic science concepts into technologies that not only solve complex, real-world problems but also expand the boundaries of fundamental science. As a national-security laboratory, Livermore has essential responsibilities for ensuring the safety and reliability of the U.S. nuclear stockpile and the credibility of the U.S. nuclear deterrent.

We also apply Livermore's core capabilities, through multidisciplinary project teams, to other problems of national importance. We focus on projects that require a combination of capabilities unavailable elsewhere. The scientific breakthroughs and technical innovations made in these projects enhance our national-security work, and many find applications of direct public benefit. Examples include:

• **High-power lasers,** such as the Nova laser and the proposed National Ignition Facility, are used for unique weapons-physics experiments and for research leading to fusion energy production. Livermore's laser program has spurred major advances in the U.S. precision-optics industry.

• **Atomic vapor laser isotope separation (AVLIS);** uranium-AVLIS is in the process of commercialization and has the potential to help the U.S. retain and increase its major share of the multibillion-dollar-a-year global market in fuel for nuclear power plants.

• **Computer modeling codes, such as DYNA3D,** that dramatically cut the time and expense required to analyze the safety adequacy of structures and mechanical systems and to optimize the design of new products.

• **Digital mammography and computed tomography,** adaptations of advanced imaging and image-processing methods developed for nondestructive inspection of nuclear weapons, have the potential to greatly improve the diagnosis of breast cancer and other medical conditions.

• **Human genome, DNA repair, and food mutagen research,** all of which require a marriage of cutting-edge bioscience with the ultraprecise chemistry, high-performance computing, advanced instrumentation and engineering, and experimental facilities that were developed initially at Livermore for national-security work. These spinoff projects are revolutionizing the understanding of human health and health care.

• **Dynamic underground stripping , microbial filters,** and other innovative *in situ* environmental remediation technologies are increasing the speed and effectiveness and decreasing the cost of environmental cleanup.

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Work performed under the auspices of the U.S. Department of Energy by
Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

University of California
Lawrence Livermore National Laboratory

Defense and Nuclear Technologies Directorate

February 1996

UCRL-MI-121423-DNT Rev. 1

Our work in defense and nuclear technologies helps to ensure national security and reduce the nuclear danger

Mission

The Defense and Nuclear Technologies (DNT) Directorate is responsible for ensuring the safety, reliability, and security of the U.S. nuclear stockpile without nuclear testing, for developing advanced manufacturing and materials technologies to maintain the enduring stockpile, and for ensuring the safe dismantlement of retired weapons. Multidisciplinary teams apply this unique expertise to the development of technologies that reduce U.S. vulnerability to terrorist nuclear threats and that enhance the nation's conventional defense.

Weapons science

The knowledge unique to nuclear weapons physics exists only at the two weapons design laboratories. Weapons science includes:

- **Nuclear weapon physics:** Theory, experimentation, and computations of physical properties and phenomena relevant to the safety, security, performance, and reliability of nuclear weapons.
- **Computer simulation:** Computational modeling of nuclear devices using state-of-the-art computers, physical and mathematical models, and databases.
- **Hydrodynamic experiments:** High-speed, high-resolution experiments to study implosions of primaries and assure their safety and reliability; hydrodynamic test facilities are being upgraded to compensate for the absence of nuclear testing.
- **High-power laser experiments:** Experiments with Nova to measure high-temperature and high-density phenomena related to thermonuclear weapons; the planned National Ignition Facility will bring us closer than any existing laboratory facility to the conditions that occur in a nuclear explosion.
- **Materials technology:** Development of new materials and environmentally sound methods for fabrication of replacement weapon components and disposition of retired weapon materials.
- **Stockpile maintenance:** Monitoring and testing of stockpile weapon components to ensure safety, security, and reliability; transformation of physics ideas into workable engineering solutions to meet stockpile needs.
- **Arms control and nonproliferation:** Assessments of intelligence data; evaluations of the proliferation potential of suspect nations; analysis of force structures; studies of arms-control and nuclear-weapon-related policies.

Benefits to the nation

Nuclear deterrence remains a cornerstone of U.S. national-security policy. However, the cessation of nuclear testing and the termination of new weapon development have fundamentally altered the way the weapons laboratories ensure stockpile safety and reliability. Livermore has been a leader in the development of the Stockpile Stewardship and Management Program, a science-based approach for ensuring stockpile safety, security, and reliability that relies on enhanced experimental, computational, and weapons maintenance capabilities. A wealth of technological spinoffs from our nuclear weapons program, including computer codes like DYNA3D and global climate models, miniaturized electronics and instrumentation, lasers, and precision fabrication technologies, also benefit the nation.

Recent Accomplishments

• Major progress in implementing science-based stewardship of the enduring U.S. stockpile.
• Resolution of serious weapons dismantlement problems through the development of corrective procedures.
• Development of new capabilities for detecting terrorist weapons and rendering them safe.
• Design and demonstration of a new gamma-ray camera for hydrodynamic testing. This camera produces images of much greater detail (more than double the resolution) than was possible with previous instruments and can obtain images at much later stages in the implosion process.
• Development of the concept for reusing plutonium pits from retired weapons and development of a precision die-casting method for producing new plutonium components with considerable waste reduction.
• Development of a self-contained apparatus for transforming plutonium pits into a form suitable for disposal as well as other methods for safely disposing of weapon materials.

New initiatives

Livermore is working on several new initiatives that formalize existing efforts:
• **Dual Revalidation.** Two independent teams, one from our laboratory and Sandia-Livermore and the other from Los Alamos and Sandia-Albuquerque, will analyze the safety and performance of each stockpile weapon system with our most modern computational and experimental tools. Livermore played a key role in demonstrating the need for this fundamental approach to independent technical evaluation.
• **Accelerated Strategic Computing initiative.** Dramatically improved computational capabilities will be developed to provide the enhanced technical and quantitative foundation for the judgment-based stockpile decisions that will be required in the absence of nuclear testing.
• **Advanced Design and Production Technology initiative.** Advanced manufacturing technologies and processes will be developed to enable affordable production of high-quality, variable-lot components for stockpile maintenance.
• **Enhanced Surveillance initiative.** New predictive capabilities will be developed for early detection of age-related changes that affect weapon safety or reliability.
• **National Ignition Facility.** Major progress is being made in determining the facility and diagnostics requirements for experiments to study weapons physics issues with the National Ignition Facility.
• **Flash X-Ray facility upgrade.** This existing hydrodynamic test facility is being upgraded to provide two x-ray pulses, and hence two images, during a primary implosion. This technology, combined with a dual-x-ray-beam capability being built at Los Alamos, will be the basis for three-dimensional CAT-scan-like movies of the interior of an imploding primary.

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Work performed under the auspices of the U.S. Department of Energy by
Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

University of California
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Nonproliferation, Arms Control, and International Security Directorate

November 1995

UCRL-MI-121428-NAI

We work to reduce nuclear proliferation and the threats from weapons of mass destruction

Mission

The Nonproliferation, Arms Control, and International Security (NAI) Directorate provides technology, analysis, and expertise in support of national and international efforts to reduce the threats from nuclear weapons and other weapons of mass destruction.

Reducing Nuclear Dangers

The NAI Directorate draws on Livermore's expertise in nuclear weapons, weapon technology, and other multidisciplinary strengths in pursuit of its national- and global-security mission. Activities include:

- Analysis of foreign weapon activities.
- Development of new technologies for detecting and monitoring nuclear weapons programs and for monitoring and safely disposing of nuclear materials.
- Technical support to the U.S. government for the development of arms-control policy and for negotiation and monitoring of arms control and test ban treaties.
- Defense conversion efforts in the republics of the former Soviet Union.
- Development of technologies for responding to threats of nuclear terrorism and other nuclear emergencies.
- Assistance to the U.S. government in assessing the effects of possible counterproliferation strategies through computer-based conflict simulation and comprehensive systems analysis.

Recent Accomplishments

- Development and testing, in collaboration with Russian scientists, of nuclear-material monitoring equipment as part of U.S.–Russian agreements on the dismantlement and storage of nuclear weapons.
- Assessments of foreign nuclear weapon capabilities and programs to support U.S. policy in regions with nuclear weapon activities.
- Delivery of monitoring equipment to Iraq for the United Nations Special Commission.
- Provision of equipment for weapon dismantlement and nuclear accident response to republics of the former Soviet Union.
- Provision of negotiation support and execution of critical experiments to guide comprehensive test ban discussions at the Conference on Disarmament.
- Development of portable chemistry laboratories for monitoring the Chemical Weapons Convention.
- Demonstration of a new and efficient method to convert plutonium from nuclear weapons directly to usable reactor fuel.
- Development of advanced computer simulation tools within a nationally accessible facility for training and educating military and government organizations in counterproliferation and crisis situations.

National Assets

We contribute to U.S. national security by providing expertise, technology, and support through a number of unique centers and capabilities:

- Forensic Science Center.
- Communicated Threat Evaluation Center.
- Conflict Simulation Laboratory.
- Proliferation Assessment Program.
- The Department of Energy's Nuclear Emergency Search Team.

Benefits to the Nation

Livermore expertise in nuclear weapon science and technology provides the foundation for our nonproliferation and counterproliferation activities, and these activities help maintain our overall nuclear weapons expertise. We also draw on laboratory capabilities in physics, engineering, chemistry, metallurgy, computing and computer systems, political science, and intelligence analysis. Applying this multidisciplinary, multiprogram expertise, the NAI Directorate develops, for instance, state-of-the-art sensors for detecting clandestine weapons programs and provides accurate and reliable assessments for U.S. policy-makers and the intelligence community. Coordinated technology development, defense conversion, and economic development programs with scientific institutes and industries of the former Soviet Union are also contributing to the reduction of nuclear dangers worldwide.

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Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

University of California
Lawrence Livermore National Laboratory
Laser Programs Directorate
November 1995
UCRL-MI-121427-LA

Livermore's Laser Programs comprise the world's premier center for lasers and electro-optics R&D

Mission

Livermore is a world leader in laser and electro-optic science, engineering, and technology. We are applying this expertise to meet national needs in the diverse areas of energy, the environment, the economy, and defense. We are extending our collaborations with industry and other institutions to identify technologies that can be developed and transferred to the private sector.

Technical Diversity and Unique Programs

Our principal laser projects derive from the core intellectual and technical capabilities developed for national security and involve the full complement of Livermore's multidisciplinary expertise. We have two long-standing major programs:

• **The Inertial Confinement Fusion (ICF) Program** has made great advances in understanding the scientific principles of ICF. Livermore's Nova laser is the principal experimental tool for our ICF activities. We are advancing ICF technology as an environmentally clean source of energy, providing improved understanding in many areas of basic science, and contributing to economic and national security. The next-generation ICF laser facility, the National Ignition Facility, is now under development at Livermore, in conjunction with the Los Alamos and Sandia national laboratories and the University of Rochester.

• **The Isotope Separation and Advanced Manufacturing Program** has two components: atomic vapor laser isotope separation (AVLIS) and advanced manufacturing. AVLIS is directed primarily toward the development of low-cost, environmentally responsible enrichment of uranium for fission reactor fuel; we are currently transferring the AVLIS technology for uranium enrichment to the private sector. Our advanced manufacturing activities are directed toward the development and demonstration of innovative uses for AVLIS technology.

In addition, we are further developing very successful programs in the areas of:

• Imaging and detection.
• Advanced microtechnology.
• Remote sensing.

Besides major contributions in basic science, technology, and applications over the past decade, these programs have provided significant advances in:

• Optics
• Diagnostics and sensors
• Materials handling and processing
• Microfabrication, microelectronics, and information technologies.
• Plasma physics and fusion research.

Derivative Applications

Numerous derivative applications of our scientific base and expanding technologies are being assessed and pursued as potential new programs in such areas as:

- Micropower impulse radar (radar on a chip)
- Soft-x-ray projection lithography
- Laser tracking and adaptive optics for astronomy applications.
- Diode-pumped solid-state lasers
- Short-pulse high-irradiance lasers.
- Remote materials handling.
- Materials processing.
- Laser and radar remote sensing.
- X-ray lasers.
- Tactical battlefield weapons.

Recent Accomplishments

- Development of the Nova laser, the world's most powerful and continuously operating laser.
- Development of world-leading laser technology and applications.
- Development of new technologies and techniques for safely maintaining the U.S. nuclear stockpile without underground testing.
- Research assessing the feasibility of inertial fusion energy as a long-term, clean energy source.
- Development of ICF optics technology, which was applied by a U.S. company in making to the corrective lenses for the Hubble Space Telescope.
- High-energy-density research providing insights into the origin of matter and the universe.
- Invention of low-cost, micropower impulse radar with extensive automotive, industrial, health care, and security applications.
- Development of micromanufacturing technologies leading to smaller computer chips and circuits.
- Development, demonstration, and transfer of technology to industry of a low-cost uranium-enrichment technology (AVLIS) for fuel for nuclear power plants.
- First demonstration of laboratory x-ray lasers and first production of three-dimensional x-ray holographic images.

Internationally Recognized Technical Staff

The scientific and technical excellence of our Laser Programs staff is widely recognized nationally and internationally. Our researchers include 36 fellows of professional research societies. Over the years, Laser Programs personnel have received two Maxwell awards, four Excellence in Plasma Physics awards, four E. O. Lawrence awards, three Edward Teller awards, and 25 R&D 100 awards, among others. Livermore's contributions in laser technology and its applications range from new visions in industry and defense to micro-optics for improving human vision. Our skill in translating this knowledge base into outstanding technological innovation is a vital characteristic and continuing goal of the Laser Programs.

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Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

University of California
Lawrence Livermore National Laboratory
Energy Directorate

November 1995
UCRL-MI-121424-EP

Livermore's energy technologies benefit the U.S. economy, the environment, and national security

Mission

In the Energy Directorate, we draw on Livermore's multidisciplinary strengths to develop energy technologies that enhance national security, are economically feasible and safe, and have minimal environmental impact. We work with industry to ensure commercialization of these technologies. We support U.S. policy makers with data in the energy arena, and we address energy issues that are beyond the resources of industry.

Worldwide Challenges

Attaining long-term, ecological, and economic solutions to meet the world's need for energy demands excellent science and requires the best efforts of multiple scientific and political institutions. Energy use, transportation, manufacturing, and waste handling are interrelated challenges requiring integrated solutions. In our research, we collaborate with other national laboratories and government agencies, U.S. industry, universities, and international partners to meet these challenges.

Our energy work capitalizes on Livermore's hallmark capability to develop novel scientific concepts and transform them into working prototypes to solve real-world problems. Many weapons-program technologies have found spinoff applications in the energy arena.

Energy Programs

Four programs comprise the Energy Directorate:

- **Magnetic Fusion Energy:** Livermore is a strong player in the international effort to develop a magnetic fusion reactor as a source of electric power for the 21st century. We are also exploring alternative concepts for fusion reactors to reduce size, complexity, and cost.
- **Fission Energy and Systems Safety:** Livermore's multidisciplinary engineering and scientific strengths are applied to resolve technical issues that inhibit public acceptance of nuclear power, including safety, life-cycle management of nuclear materials, and nuclear proliferation.
- **Energy, Manufacturing, and Transportation Technologies:** Livermore technologies are being adapted to applications in energy, manufacturing, materials, and transportation. For example, we are helping to develop an automotive power system that meets established future performance requirements, including issues of fuel supply, emissions, materials, economics, safety, and manufacturability.
- **Energy Analysis, Policy, and Planning:** Consonant with Congressional and Administration direction, we do long-range planning regarding Livermore's energy work and identify new research directions.

Recent Accomplishments

- Formulation of concepts for advanced tokamaks, including the Tokamak Physics Experiment (TPX), to lower the anticipated cost of fusion-generated electricity.
- Remote operation of fusion facilities via the Internet and development of distributed computing architecture for sharing experimental data in real time. This process was demonstrated recently when the tokamak at the Massachusetts Institute of Technology was operated from a Livermore control room.
- Significant responsibility for engineering design and R&D for the International Thermonuclear Experimental Reactor.
- Provision of personnel for on-site inspection teams, as called for in the highly enriched uranium transparency agreement between the U.S. and the former Soviet Union.
- Development of a concept that would keep nuclear waste packages at the proposed Yucca Mountain repository dry for 5000 years, thus ensuring substantially complete containment.
- Technology development for the use of hydrogen as a transportation fuel, including the concept for a mechanical equivalent of the fuel cell that can be used to power a hybrid vehicle.
- Development of a flywheel battery that can be used for stationery storage and power conditioning and for transportation.
- Development and refinement of superplastic steel and aluminum alloys suitable for near-net-shape processing to minimize waste.
- Fabrication of two mirrors for the Keck telescope in Hawaii, using Livermore's Large Optics Diamond Turning Machine.

Benefits to the Nation

Energy is the driver for all economies and is essential for national security; however, energy production and energy use account for much of the world's pollution. Livermore is striving to become a leader in industrial ecology as we apply our multiprogram, multidisciplinary approach to solving complex problems and developing a broad range of integrated technologies—from fusion to flywheel batteries—to help the nation make better use of all of its energy resources. These technologies focus on sustainable energy use and on meeting the long-term strategic needs of the nation. These technologies should also provide the U.S. with opportunities for marketing to developing nations, where energy use is rapidly increasing.

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Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

University of California
Lawrence Livermore National Laboratory

Environmental Programs Directorate

November 1995

UCRL-MI-121426-ENV

Our research mitigates environmental hazards and repairs environmental damage

Mission

Livermore's Environmental Programs conduct multidisciplinary research to assess and mitigate environmental and human risk from natural and man-made hazards and to develop and demonstrate new tools and technologies for environmental restoration.

Broad-Ranging Environmental Research

Much of the science and many of the technologies now being used for environmental research originated in the nuclear weapons program. Livermore's earliest meteorology efforts were conducted to ensure that prevailing winds would not carry radioactive debris from atmospheric tests over populated areas. With the advent of underground testing, Livermore began studies in geology, geochemistry, and geophysics to ensure containment of the underground nuclear blasts. The Atmospheric Release Advisory Capability (ARAC) was initially established, using codes and scientific understanding developed in the weapons program, to predict and track releases of radioactivity to the atmosphere. Environmental remediation efforts were begun to clean up the legacy wastes of 50 years of nuclear weapon production.

In collaboration with other federal agencies, we now have multidisciplinary project teams investigating all facets of the environment, from deep within the Earth to the land surface and from groundwater to the upper reaches of the atmosphere. Current areas of research include:

- Atmospheric radiative transfer, chemistry, dynamics, and climate processes.
- Physics of the atmospheric boundary layer and cloud processes.
- Seismic processes.
- Geochemistry and geophysics.
- Pathway, dosimetry, and risk analysis of radioactive and toxic substances.
- Isotopic and ion beam sciences.
- Modeling of subsurface flow and transport.
- Subsurface imaging and characterization.
- *In situ* environmental remediation using natural and engineered processes.
- Design, analysis, and testing of advanced waste-treatment technologies.

Benefits to the Nation

Our environmental programs range from emergency response activities to environmental policy assessments. Seismic studies, derived in part from underground nuclear testing research, have led to better design criteria for reactors and other critical structures. Geoscience studies have led to novel site-remediation technologies. Working in teams with other Livermore programs and directorates, we have developed new methodologies for water purification, waste treatment, and dose assessment from radionuclide exposure. Atmospheric science studies have helped

define international protocols for chemicals that are routinely released to the atmosphere. Other projects have led to the development of emergency-response capabilities for atmospheric releases of toxic material. For much of this work, we collaborate with other government agencies. For example:

- Stratospheric dynamics and chemistry—Federal Aviation Administration.
- Global chemistry—NASA.
- Geology and geoscience—U.S. Geological Survey.

Recent Accomplishments

- Operation and continuing development of the Atmospheric Release Advisory Capability (ARAC), a Department of Energy emergency response resource that has been used in the Three Mile Island and Chernobyl nuclear reactor accidents, the Persian Gulf War, a sulfuric acid plume from a refinery spill, and numerous other incidents and emergency-response exercises.
- Leading participation in the Program for Climate Model Diagnosis and Intercomparison (PCMDI), an international climate research program.
- Development and operation of the Center for Accelerator Mass Spectrometry (CAMS), an international user facility for isotopic studies for global climate, food mutagen, archaeological, and other research.
- Development and demonstration of capacitative deionization using carbon aerogel electrodes, an innovative water purification technology.
- Design of the Mixed Waste Management Facility, a pilot-scale waste-treatment demonstration facility.
- Development and demonstration of dynamic underground stripping and microbial filtering for *in situ* site remediation.

Technical Excellence

Livermore's broad range of scientific and technical excellence, together with its ability to integrate those skills into multidisciplinary teams, provides an excellent resource for addressing complex environmental issues. Our achievements exemplify Livermore's hallmark ability of turning scientific concept into working prototypes and problem solutions. Much of our work is focused on determining and mitigating the risks and impacts of natural and man-made hazards and on remediating environmental damage. We also provide science and technology that supports Livermore's environmental compliance requirements. A number of our projects address environmental issues of global significance, and many of our scientists are participants on national and international science and policy committees.

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Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

University of California
Lawrence Livermore National Laboratory

Biology and Biotechnology Research Directorate

November 1995

UCRL-MI-121420-BBR

Our biological research helps to understand disease and to lower health-care costs

Mission

The Biology and Biotechnology Research Directorate, which stems from our work on the biological effects of radiation, conducts basic and applied research in the health and life sciences in support of national needs and to understand the causes and mechanisms of ill-health effects, prevent disease, and lower health-care costs. Knowledge gained and the science and technology developed are transferred to research institutions, industry, universities, and other agencies so that the general public can benefit directly and rapidly from our advances.

Fields of Research

Livermore continues to make many important and unique contributions in the field of bioscience and biotechnology. This success results from our ability to bring together, at one laboratory, multidisciplinary expertise in biology, chemistry, high-performance computing, and advanced instrumentation and engineering as well as access to such unique experimental facilities as Livermore's Center for Accelerator Mass Spectrometry. Our activities fall under four programs:

- **Genomics:** Livermore is one of three DOE Human Genome Centers. We develop recombinant DNA clones, DNA mapping and sequencing techniques, and instrumentation and informatics tools to characterize the genes of humans, microorganisms, animals, and plants. By combining Livermore's multidisciplinary skills and weapons engineering capabilities, Livermore teams have developed critical instrumentation such as high-speed flow cytometers. Such instrumentation, used in conjunction with Livermore expertise in high-performance computing and biotechnology, has rapidly accelerated the pace and extent of our Human Genome Project.
- **Health Effects:** As part of our historical program to study the effects of nuclear weapons, Livermore developed techniques for biological dosimetry that are now used to assess biologically relevant exposure to toxic agents, carcinogens, and mutagens. Our current health-effects research integrates studies in DNA repair, the genetics of cancer susceptibility, and biodosimetry.
- **Structure–Function Analysis:** In studies related to cancer and human disease, we investigate, on the molecular level, proteins that are responsible for maintaining the integrity of the human genome, the effects of defective protein production or function, and the damage produced by small molecules that bind to and alter DNA.
- **Health Care:** The Center for HealthCare Technologies focuses multidisciplinary, multiprogram efforts on novel applications of Livermore-developed technologies for the diagnosis, treatment, and/or prevention of disease, for minimally invasive medicine, and for information management.

National Assets

- Human Genome Center.
- Center for Healthcare Technologies.
- Integrated structural biology.
- Genetic toxicology and biomonitoring.
- Bioinstrumentation and bioinformatics.

Recent Accomplishments

- Completion of the map of human chromosome 19 and identification of more than 250 new genes on this chromosome.
- Discovery of the structural defect resulting in myotonic dystrophy (leading to the first DNA-based diagnostic for this disease), the cause of one form of dwarfism, and a gene for cancer-susceptibility due to sun exposure.
- Measurement of extremely low levels of DNA damage in mice and humans using Livermore's Center for Accelerator Mass Spectroscopy; these levels of DNA damage are realistic with common environmental or workplace exposures.
- Development and transfer to industry of a number of biomedical technologies, including a high-speed flow cytometer and sorter, our "chromosome paints" technique for identifying chromosomal abnormalities, and a digital mammography instrument design.
- Significant improvement in the collection of x-ray diffraction data by cooling protein crystals to 125 K (–148°C), making possible the highest-resolution (1.0-Å) dataset ever achieved for a single crystal of a protein.

Benefits to the Nation

Livermore's Biology and Biotechnology Research Directorate is an acknowledged world leader in molecular genetics and genomics, human mutation and health risk assessment, molecular toxicology, and bioinstrumentation development. Using the multidisciplinary advantages at Livermore, we play a major role in the National Human Genome Project to decipher the human genetic code. The technological resources we develop and the scientific information we generate are made available to scientists throughout the world. Together with Livermore's Center for Accelerator Mass Spectrometry, we are the national source for biomedical accelerator mass spectrometry measurements. We are also the national leader in the quest to understand the cancer risks that result from consuming carcinogens created by cooking typical foods of the American diet. Through our Center for HealthCare Technologies, many of the defense technologies developed at Livermore are being adapted to create new methods for disease diagnosis, treatment, and prevention, providing improved capabilities, reduced costs, or both.

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Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

University of California
Lawrence Livermore National Laboratory

Chemistry and Materials Science Directorate

February 1996

UCRL-MI-121421-CMS Rev. 1

Our cutting-edge knowledge of chemistry and materials science supports Livermore's many projects

Mission

The Chemistry and Materials Science (C&MS) Directorate provides cutting-edge expertise in chemistry and materials science to ensure the success of Livermore's national-security mission and its related core programs. We anticipate and initiate R&D projects relevant to current and long-term U.S. technology and security needs, including science-based stockpile stewardship, the National Ignition Facility, and new energy, environmental, and health-care technologies.

Science and technology

Livermore's multidisciplinary project teams, staffed with innovative and creative scientists drawn from many scientific disciplines, include chemists and materials scientists with expertise in the following areas:

- Analytical chemistry.
- Isotope sciences.
- Nuclear instrumentation.
- Isotope hydrology.
- Energetic materials.
- Physical, inorganic, and polymer chemistry.
- Solid-state chemistry.
- Chemical engineering.
- Metallurgy and ceramics.
- Materials characterization.
- Surface sciences.
- Thin films, multilayers, and nanostructures.
- Materials theory, simulation, and modeling.

Recent Accomplishments

- Design, development, and demonstration of critical materials, processes, and surveillance tools for ensuring the safety, security, and reliability of the U.S. nuclear stockpile.
- Development of novel materials engineered on the nanometer scale with many potential industrial applications, including aircraft engines with improved performance.
- Demonstration of the applicability of aerogels for vastly improved energy storage and environmental restoration.
- Development of x-ray microtomography as a diagnostic tool for medical research.

Benefits to the nation

The C&MS Directorate provides a critical scientific and technological knowledge base necessary for the success of Livermore's multidisciplinary approach to solving real-world problems. Our progress in the nanoengineering of novel materials, such as aerogels and multilayers, has significant implications for the future of structural materials, components for energy-storage and energy-generation devices, and electronic, magnetic, and optical materials. Of equal importance is the specialized expertise of our scientists in energetic and nuclear materials, a knowledge base that is critical to national security. We also make important contributions to the quality

of the environment, both through the innovative application of materials to environmental remediation efforts and through the use of analytical and radiochemical skills to ensure that Livermore activities do not adversely affect the environment.

Technical excellence

The scientific quality of the C&MS Directorate's core strengths is recognized nationally and internationally. We have competed for and been awarded many projects in fundamental and applied science by the Departments of Energy and Defense and other government agencies. We support important Livermore programs in national security, environmental, energy, transportation, and information technologies. C&MS scientists serve on a wide range of national and international committees that are shaping the future for chemistry and materials science worldwide. Participation by the C&MS Directorate in scientific partnerships has been extensively sought by industry and the commercial sector, and these partnerships have benefited from and strengthened our core science and technology.

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Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

University of California
Lawrence Livermore National Laboratory

Physics and Space Technology Directorate

November 1995

UCRL-MI-121430-PST

Livermore's work in physics and space technologies is crucial to national security and advances fundamental science

Mission

The Physics and Space Technology (PST) Directorate performs innovative research, develops new experimental tools, and demonstrates cutting-edge technologies in physics and space science. Our efforts are critical to the success of Livermore's programs that support national security as well as those that pursue fundamental science and technology.

Physics Research at Livermore

The PST Directorate plays key roles in all of Livermore's multidisciplinary programs. Science-based stockpile stewardship, in particular, presents some very challenging problems that require advances in fundamental scientific understanding. To this end, we utilize Livermore's unique experimental facilities, large-scale computer codes, and advanced supercomputers. We are collaborating in the Department of Energy's Accelerated Strategic Computing Initiative and are part of a multiprogram team designing the National Ignition Facility. In addition, we make significant contributions to Livermore's programs in nonproliferation, inertial confinement fusion, biology and biotechnology, energy, and the environment.

In the Livermore tradition of applying scientific expertise to solve real-world problems, we carry out research in various fields of physics, including:

- Materials physics.
- High-energy-density plasma physics.
- High-pressure physics.
- Nuclear and atomic physics.
- Computational physics.
- Space science and astrophysics.

Recent Accomplishments

- Design and demonstration of a novel sensor for nonintrusive remote identification of chemical emissions, a technology ideally suited for intelligence-gathering operations and the detection of chemical signatures indicative of covert nuclear weapons production.
- Application of Livermore's unique capabilities in plasma chemistry and pulsed-power technologies to investigate and disprove a Japanese claim of a new method for reducing nitrogen-oxide emissions from diesel engine exhaust, thus saving U.S. industry unnecessary R&D costs.
- Development of improved dose calculations for radiation treatment of cancer through the use of computer codes developed for nuclear weapons design.

Program Successes

Research conducted to address specific weapons-related issues has led to important scientific discoveries in all areas of physics and to major innovations in experimental techniques and diagnostic instrumentation. These advances have both enhanced our core weapons capabilities and opened exciting new areas of investigation.

Physics and nuclear technologies developed in Livermore's national-security work are being used in the B-Factory, a Department of Energy high-energy physics facility that is being designed and constructed by the Stanford Linear Accelerator Center and the Livermore and Berkeley laboratories. With help from Livermore, U.S. industry was awarded the largest B-Factory procurement contract, over competition from Japan's and Germany's largest firms.

In the MACHO (massive compact halo object) project, we used technologies developed by Livermore for the Department of Defense's strategic defense initiative, together with the telescope at an Australian astronomical observatory, to create a novel instrument for investigating the nature of dark matter (the missing mass) in our galaxy. The multidisciplinary team of researchers, led by Livermore, has used this instrument to make major scientific discoveries in astronomy. The U.S. Air Force and NASA are evaluating the capabilities demonstrated in this project for use in identifying potential Earth-threatening asteroids.

In the Clementine lunar mission, NASA's lunar scientists used sensor systems developed by Livermore on a spacecraft provided by the Naval Research Laboratory to completely map, for the first time ever, the surface of the moon. The information gathered by Clementine has led to major scientific discoveries regarding lunar evolution.

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Work performed under the auspices of the U.S. Department of Energy by
Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

University of California
Lawrence Livermore National Laboratory

Computation Directorate

November 1995

UCRL-MI-121422-CMP

We push the frontiers of computing science in modeling, data storage, and high-speed networks

Mission

The Computation Directorate provides state-of-the-art computer technology and services to all Livermore research projects. We are a resource of cutting-edge expertise in computers and computing science. We engage in applied research activities that advance our capabilities in computational science and support Livermore's national-security and other missions.

Computations Integral to All Research

At the inception of the national laboratory system, the compelling need for numerical simulation of nuclear explosions drove the development of the high-performance computer industry and set many of the standards for scientific computing. The ability to design nuclear weapons with only a few nuclear tests— and now to ensure the safety and reliability of the enduring U.S. stockpile without nuclear testing— is made possible by advances in our computational modeling capabilities.

Many major breakthroughs in science and technology have their origins in the weapons laboratories' expertise in modeling and simulation. Progress toward inertial confinement fusion as a practical energy source involves a closely linked modeling and experimental effort. The design of modern lasers, particle accelerators, or large experimental detectors is virtually unthinkable without extensive modeling expertise.

The Computation Directorate continues to contribute to Livermore's science and technology products through a broad array of multidisciplinary research projects sponsored by the Department of Energy, other government agencies, and industrial partners. Current projects include:

- Development and application of adaptive mesh refinement algorithms to computational fluid dynamics, vital to our national-security mission and many other related programs.
- Image processing for medical and industrial applications.
- Computational biomechanics.
- Active computer vision applications in motion detection and analysis.
- Advances in state-of-the-art high-performance data storage and data management systems.
- Development of advanced application codes for large-scale parallel processing systems.
- Climate system modeling on massively parallel systems.

• Implicit and explicit finite-element algorithms for massively parallel computers with applications in solid and structural mechanics.
• Three-dimensional simulation of plasmas and other complex phenomena important to our national-security mission.
• Applied electromagnetic simulation on parallel computers.

Recent Accomplishments

• Leader in the multilaboratory Accelerated Strategic Computing Initiative (ASCI) that will provide the computational underpinnings for science-based stockpile stewardship.
• Participation in the Industrial Computing Initiative to bring parallel computing to maturity; because massively parallel processing is an essential capability for stockpile stewardship, this partnership with U.S. industry directly contributes to our national-security mission.
• Development of new adaptive algorithms for the noninvasive monitoring of blood oxygen saturation of patients in real time.
• Completion of a nine-year effort to define, test, and promote the international CALS digital data interchange standards, which have been adopted in the U.S., Canada, Great Britain, Australia, and France.

Benefits to the Nation

Livermore is renowned for its ability to apply computer modeling and simulation to solve large, complex, multidisciplinary scientific and engineering problems. Success in achieving our national-security and related missions depends increasingly on the enabling technologies of scientific computing, high-speed communications, and large-scale information storage and retrieval.

The Computation Directorate is responsible for managing and operating two of the most powerful supercomputing centers in the world, one dedicated to defense-related applications and the other to national energy research. We also manage and operate the Energy Sciences Network (that portion of the Internet managed by the Department of Energy). High-speed networks enable unprecedented sharing of resources, including remote control of physical experiments and long-distance scientific collaborations. Equally important, we conduct independent and collaborative research in computing science that supports Livermore's multidisciplinary programs and enhances our core scientific and technical capabilities.

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Work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

University of California
Lawrence Livermore National Laboratory

Engineering Directorate

November 1995

UCRL-MI-121425-ENG

The Engineering Directorate puts science into action, working with Livermore's programs to solve problems of national importance

Mission

The Engineering Directorate works in partnership with all laboratory programs as well as with outside research organizations and industry to make the technological breakthroughs needed to solve problems of national importance.

Engineering Integrated with Programs

Unique among the national laboratories, Livermore has a large central engineering organization composed of 2100 engineers, technicians, and support people. More than 80% of these people are assigned to specific laboratory projects, often as complete engineering divisions, where they work alongside program scientists in multidisciplinary teams. These engineering divisions are critical to the success of these projects and are the *raison d'être* for the existence of the Engineering Directorate. About 10% of Engineering's staff and resources are dedicated to maintaining and enhancing the core technologies and unique engineering facilities. In this core engineering research, we anticipate and develop the technologies, tools, and facilities that will be required by future laboratory programs. Often, this work creates new opportunities for Livermore to contribute to emerging national needs and develops technologies that spin off into new programs and centers of excellence, as has happened in such areas as advanced manufacturing technology, transportation technologies, imaging science, nuclear systems safety, and health care technology. As program goals are met or needs change, the engineering teams are reassembled and reassigned, allowing the laboratory to respond effectively to changing national needs.

Engineering Core R&D

Livermore's Engineering Directorate is a multidisciplinary organization with expertise in the major engineering fields. We develop and simulate engineering systems, improve their designs, and then test their performance when built. We manage large- and small-scale projects requiring complex interactions of many scientific disciplines. In support of these activities, we have research and development efforts in the following core technologies:

- Computational electronics and electromagnetics
- Computational mechanics
- Power conversion technologies
- Information engineering
- Materials science and engineering
- Nondestructive evaluation
- Microtechnology
- Precision fabrication and manufacturing

Benefits to the Nation

The Livermore matrix style of program and laboratory management, with a strong engineering component, is a legacy of E. O. Lawrence, who pioneered the multidisciplinary team approach to applied research. It remains to this day a key factor in Livermore's outstanding successes in such programs as uranium enrichment by laser isotope separation, the design and construction of the Nova laser, the

engineering design of the National Ignition Facility, and the design and construction of the Flash X-Ray Facility (one of the nations premier diagnostic tools for science-based stockpile stewardship to assure the continuing safety and reliability of the stockpile without nuclear testing). Engineering development of precision metrology and precision diamond machining helped to develop U.S. industrial strength in areas as diverse as computer disks and contact lenses.

Major Accomplishments

- Engineering development and plant-scale demonstration of the atomic vapor laser isotope separation (AVLIS) process for uranium enrichment.
- Engineering design and construction of the Nova laser and the Flash X-Ray facility; engineering design work for the proposed National Ignition Facility.
- Continuing development of precision fabrication, including diamond machining and grinding and nanoscale fabrication.
- Development, in collaboration with biotechnology researchers, of a series of high-speed flow cytometers for sorting biological cells and cell components.
- Development of structural-mechanics codes, including CAST2D, DYNA, NIKE, ParaDyn, PING, SAND, and TOPAZ.
- Development of nondestructive inspection methods, including infrared computed tomography and laser-generated ultrasonics.
- Science and technology of structural materials, including materials processing, bonding and adhesion, and tailoring and prediction of materials properties.

Technical Excellence

In Livermore's early years, technical challenges posed by the nuclear weapons program attracted some of the nation's most talented engineers and scientists to Livermore. This legacy continues today with the challenges posed by our current programs. Many of our engineers have received national and international recognition for excellence in their technical fields.

Livermore has a large number of unique fabrication and test facilities, many of them developed initially for national-security work. Among these facilities are laboratories for nondestructive evaluation, for microfabrication of electronic and mechanical components on the nanometer scale, and for precision machining, including a large optics diamond machining facility that is unique in the world.

The Engineering Directorate brings together, in one square mile, the technical expertise and the facilities needed to tackle almost any kind of engineering problem. Applied in multidisciplinary, multiprogram project teams that produce working prototypes from scientific concepts, these resources give Livermore a capability for scientific problem-solving and technical innovation that is unmatched anywhere in the nation or the world.

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Work performed under the auspices of the U.S. Department of Energy by
Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.

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Lawrence Livermore National Laboratory

Plant Operations Directorate

November 1995

UCRL-MI-121429-PO

Plant Operations provides efficient, cost-effective services to support Livermore's research activities

Mission

The Plant Operations Directorate provides Livermore—the laboratory, its research programs, and its employees—with cost-effective support in environment, safety, and health, quality assurance, emergency preparedness, physical plant, and information services.

Directorate Functions

Multidisciplinary skills and talents are applied in all of Plant Operations' activities:

- Protection of the environment via environmental monitoring, compliance, restoration, and waste management activities.
- Fostering of a safe working environment, with appropriate safety training and education for employees.
- Readiness programs to ensure that Livermore is in a constant state of preparedness to respond to and manage any on-site incident resulting from or affecting laboratory activities or personnel.
- Protection of the health of Livermore employees.
- Guidance and training in quality assurance and administration of human reliability programs tailored for specific Livermore projects.
- Services for site planning, design and construction management, and maintenance, operations and utilities.
- Information and communication services through library resources, publications support, business information systems, and telephone, computer networking, and telecommunication systems.

Benefits to the Laboratory

The Plant Operations Directorate provides Livermore with environment, safety, and health (ES&H) and quality assurance (QA) expertise and technical support. Multidisciplinary teams, with staff drawn from within and outside the directorate, assist Livermore researchers in implementing ES&H and QA policies and complying with regulatory and contractual requirements cost-effectively and with minimal interference to their research projects.

ES&H organization and oversight are implemented primarily from within the Plant Operations Directorate:

- **Environmental Protection Department:** Ensures that current projects and operations do not adversely affect the environment and implements technologies to remediate environmental contamination at Livermore from past activities to acceptable environmental standards. Plant Operations staff work with regulators and stakeholders to resolve regulatory compliance issues and promote risk based policies.

• **Hazards Control Department:** Oversees and integrates risk minimization, control of workplace hazards, and employee safety training.
• **Emergency Preparedness Program:** Prepares for and manages emergencies while protecting the health and safety of Livermore employees and the public.
• **Health Services Department:** Protects, maintains, and improves the health of Livermore employees.
• **Laboratory Assurance Office:** Oversees Livermore's quality assurance program and administers the DOE-mandated human reliability programs for laboratory employees in safety- and security-sensitive positions.

Other infrastructure services are provided through:
• **Plant Engineering Department:** Provides site planning and facilities design, construction, and maintenance.
• **Information Systems Departments:** Provides telephone and telecommunications systems; delivers scientific, technical, and corporate information to internal and external customers with library, archive, publications, and business information services.

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Work performed under the auspices of the U.S. Department of Energy by
Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.